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Silver Lake East Dam, MT 3752, Silver Lake West Dam, MT 3753, Anaconda, Montana, Deer Lodge County

ASE I INSPECTION REPORT
IONAL DAM SAFETY PROGRAM

SILVER LAKE EAST DAM
MT 3752

SILVER LAKE WEST DAM
MT 3753

ANACONDA, MONTANA
DEER LODGE COUNTY

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prepared by:

HKM ASSOCIATES
BILLINGS, MONTANA

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PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

SILVER LAKE EAST DAM
MT 3752

SILVER LAKE WEST DAM
MT 3753

ANACONDA, MONTANA

DEER LODGE COUNTY

PREPARED FOR:

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EXECUTIVE SUMMARY

Personnel of HKM Associates, under a contract with the Montana Department of Natural Resources and Conservation (DNRC), and with representation from the DNRC, and the Anaconda Copper Mining Company (project owner/operator), inspected Silver Lake East Dam and Silver Lake West Dam on September 30, 1980. The inspection and evaluation were performed under the authority of Public Law 92-367.

Silver Lake is located 12 miles west-northwest of Anaconda, Deer Lodge County, Montana. Silver Lake is contained by a dam on both the east and west side. The containment structures are identified as Silver Lake East Dam, MT 3752 and Silver Lake West Dam, MT 3753. Both dams were constructed by the Anaconda Copper Mining Company. Available information indicates that the east dam was constructed in about 1918 and the west dam was originally constructed in about 1902 and later modified in about 1918.

FINDINGS AND EVALUATION

Silver Lake stores runoff from a natural drainage of 1.9 square miles, with supplemental supply from Twin Lakes, Storm Lake, and reregulation from Georgetown Lake. The primary purpose for stored water in Silver Lake is industrial water supply for the mining operation. Secondary benefits are provided for irrigation, municipal water supply, recreation, sediment accumulation, and flood control. Active storage capacity of the lake to the normal pool level is 17,570 acre-feet (AF). Total storage capacity to first overtopping dam crest elevation, at the east dam, is 17,920 AF. The reservoir pool can raise an additional foot before overtopping would occur at the west dam. The total storage capacity associated with overtopping at the west dam is 18,280 AF. The storage actually contained by the dams is 2100 AF and 4170 AF for the east dam and west dam, respectively. The remaining storage would be contained by the natural pool in the case of a dam breach. Water can be released from the natural pool by pumping. Silver Lake East Dam has a hydraulic height of 6.5 feet and Silver Lake West Dam has a hydraulic height of 13.5 feet. On the basis of criteria in the U.S. Army Corps of Engineers' Recommended Guidelines for Safety Inspection of Dams (Ref. 1), the dams are classified intermediate in size. Based on a visual reconnaissance and engineering judgment, at least three residences, as well as miscellaneous roads and utilities, will be affected by a sudden breach of either dam. A sudden breach of either dam could also jeopardize life downstream. The downstream hazard potential for both dams is, therefore, high (Category 1). However, no dam breach analysis or routing of a dam breach flood was made of the downstream area for either dam. The conclusions on probable damage are based on a brief field inspection and engineering judgment.

The guidelines recommend that the discharge and/or storage capacity of an intermediate-size, high downstream hazard potential dam be capable of safely handling the probable maximum flood (PMF). The PMF is the flood expected from the most severe combination of meteorologic and hydrologic conditions that are reasonably possible in the region. Routing of the estimated PMF developed for the safety evaluation of Silver Lake showed that the project has a capacity of controlling a flood having hydrograph ordinates approximately equal to 37 percent of the PMF hydrograph ordinates. The east dam is the first to overtop. The west dam may also overtop if the east dam does not fail rapidly. The embankment materials for Silver Lake East Dam and Silver Lake West Dam are classified as being moderately to highly erodible and can be expected to remain stable for a limited time under an overtopping condition.

The results of the surficial examination of Silver Lake East Dam generally indicate that the embankment structure is stable, however, there is a high seepage path through the embankment and significant seepage quantities downstream. Soil piping and significant embankment sloughing were not observed, and settlement does not appear to be a problem. Apparently there is no seepage control system. Because of the seepage and possible related problems such as soil piping, sloughing and erosion, the stability of the downstream embankment probably does not conform to the recommended guidelines.

The stability of the Silver Lake West Dam embankment does not appear to meet the criteria in the recommended guidelines. Seepage through the embankment is evident as a portion of the downstream slope is saturated and there is standing seepage water at the toe of the embankment. Topsoil sloughing was observed on the downstream embankment slope. There is a lack of riprap at some locations on the upstream face of the embankment. As with Silver Lake East Dam, inadequate data is available to fully evaluate embankment stability.

There are no spillways at Silver Lake East Dam or Silver Lake West Dam.

The comparison of report findings with inspection guidelines shows the Silver Lake storage project to have insufficient storage and/or discharge capacity to safely handle the recommended spillway design flood (SDF) developed during this safety evaluation, which is the full PMF. Silver Lake storage project does not conform to the recommended guidelines. Due to the complex nature of this project and the lack of an uncontrolled spillway system, additional study is required to adequately determine the hydraulic safety of this project.

RECOMMENDATIONS

Immediately develop, implement, and periodically test an emergency warning plan for use in the event of dam distress at the east and/or west dam. Raise the dam embankments in critically low areas and/or modify the project operation plan so as to provide adequate vertical distance between the normal pool level and the first overtopping dam crest elevation to allow for wave runup. Using suitable material, fill and properly compact all localized depressions along the dam crests related to traffic damage. Perform the following repairs on the west dam outlet works: repair the concrete deterioration at the inlet and outlet structures, and make the necessary repairs to stabilize the channel banks in the stilling pool downstream of the pipe outlet. Additional rock riprap is required along the upstream face of the Silver Lake West Dam embankment and around the Silver Lake West Dam outlet structure. Repair the small timber bridge on the west dam embankment that provides access to the outlet gate controls.

Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required storage/outflow capacity and modify the project as studies indicate. Consider building an uncontrolled spillway to provide a more positive control on the maximum operating lake level. Have a qualified geotechnical engineer evaluate both dam embankments for stability and seepage using recommended guideline criteria. Conduct periodic inspections by qualified engineers at least once every five years, and include an inspection of all conduits through the embankments in this program. Maintain an active maintenance program for the dams and appurtenant structures.

Prior to performing engineering studies and remedial construction, coordinate the work with the State of Montana DNRC, Dam Safety Section, to insure compliance with all pertinent laws and regulations.

Mike Keene

Michael D. Keene, P.E.

MONTANA
MICHAEL D. KEENE 4197 E
REGISTERED PROFESSIONAL ENGINEER

PERTINENT DATA SUMMARY

1. General

Federal ID Number (Silver Lake West Dam)	MT 3753
Location	Section 21, T5N, R13W, MPM; about 9 miles west of West Valley, MT
Federal ID Number (Silver Lake East Dam)	MT 3752
Location	Section 22, T5N, R13W, MPM; about 9 miles west of West Valley, MT
County, State	Deer Lodge County, Montana
Owner and Operator	Anaconda Copper Mining Company
Purpose	Industrial water supply
Watershed	The principal sources of water are Storm Lake, Twin Lakes and Georgetown Lake. The natural drainage basin is 1.9 square miles.
Hazard Potential	Category 1 (High)
Size Classification (Silver Lake West Dam)	Intermediate
Size Classification (Silver Lake East Dam)	Intermediate

2. Reservoir

Estimated Surface Area at Normal Pool Level Elevation 6484.5 feet (see note page x)	340 acres
Active Storage to Normal Pool Level Elevation 6484.5 feet	17,570 acre-feet

PERTINENT DATA SUMMARY
(Continued)

Flood Surcharge Storage to First Overtopping East Dam Crest Elevation 6485.5 feet	350 acre-feet
Total Storage to First Overtopping East Dam Crest Elevation 6485.5 feet	17,920 acre-feet
Storage Controlled by East Dam at First Overtopping East Dam Crest Elevation 6485.5 feet	2100 acre-feet
Storage Controlled by West Dam at First Overtopping West Dam Crest Elevation 6486.5 feet	4170 acre-feet
Total Natural Drainage Area	1.9 square miles
Reservoir Water Surface Elevation on Day of the Inspection	6482.2 feet

3. Outlet Works West Dam

Gate	45-inch diameter slidegate
Control	Manual operator
Pipe	About 110 feet of 45-inch diameter steel pipe with concrete encasement.
Capacity	
To Normal Pool Level Elevation 6484.5 feet	120 cubic feet per second
To First Overtopping East Dam Crest Elevation 6485.5 feet	130 cubic feet per second

4. Outlet Works East Dam

High Level Outlet	
Gate	30-inch diameter slidegate

PERTINENT DATA SUMMARY
(Continued)

Control	Manual operator
Pipe	About 50 feet of 30-inch diameter metal pipe.
Capacity	
To Normal Pool Level Elevation 6484.5 feet	37 cubic feet per second
To First Overtopping East Dam Crest Elevation 6485.5 feet	39 cubic feet per second
Low Level Outlet	
Pumps	2-250 horsepower vertical turbine pumps
Pipes	About 600 feet of 30-inch diameter metal pipe and concrete pipe
Capacity (Estimated based on information from the operator)	350 cubic feet per second
Combined High and Low Level Outlet	About 1200 feet of 30-inch diameter wood-stave pipe

5. Other Appurtenances

At East Dam	
Supply Canal	
Type	Trapezoidal, earth canal
Source	Storm Lake
Length	1.1 miles
Design Capacity	Unknown

PERTINENT DATA SUMMARY
(Continued)

Supply Canal	
Type	Wood flume, trapezoidal, asphaltic-paved canal and rectangular, wood flume
Source	Twin Lakes
Length	3.4 miles
Design Capacity	Unknown
At West Dam	
Type	2 miles of 30-inch diameter steel pipe for pumping water from Georgetown Lake
6. East Dam	
Type	Earth fill
Structural Height	Approximately 11 feet
Hydraulic Height	6.5 feet
Design Crest Control Elevation	6489.0 feet
Existing First Overtopping Dam Crest Elevation	6485.5 feet
Crest Length	Approximately 1012 feet
Design Dam Crest Width	10 feet
Existing Dam Crest Width	Varies from 12 to 25 feet
Design Upstream Dam Slope	1V on 2.5H
Existing Upstream Dam Slope	Varies from 1V on 2.5H to 1V on 1.8H
Design Downstream Dam Slope	1V on 2H

PERTINENT DATA SUMMARY
(Continued)

Existing Downstream Dam Slope	Varies from 1V on 1.7H to 1V on 2.0H

7. West Dam

Type	Earth fill
Structural Height	Approximately 17 feet
Hydraulic Height	13.5 feet
Design Crest Control Elevation	6489.0 feet
Existing First Overtopping Dam Crest Elevation	6486.5 feet
Crest Length	Aproximately 1292 feet
Design Dam Crest Width	12 feet
Existing Dam Crest Width	Varies from 15 to 20 feet
Design Upstream Dam Slope	1V on 1.5H
Existing Upstream Dam Slope	Varies from near vertical to 1V on 2H
Design Downstream Dam Slope	1V on 1.5H
Existing Downstream Dam Slope	Varies from 1V on 1.4H to 1V on 2H

Note: All project elevations are relative to local datum. The September 30, 1980 survey was based on the water surface elevation at the time of survey, which was measured on the staff gage in the pump house to be 6482.2 feet.

CHAPTER 1
BACKGROUND

1.1 INTRODUCTION

1.1.1 Authority

This report summarizes the Phase I inspection and evaluation of Silver Lake West Dam and Silver Lake East Dam. The project is owned and operated by the Anaconda Copper Mining Company.

The National Dam Inspection Act, Public Law 92-367 dated August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to conduct safety inspections of non-federal dams throughout the United States. Pursuant to that authority, the Chief of Engineers issued "Recommended Guidelines for Safety Inspection of Dams" in Appendix D, Volume 1 of the U.S. Army Corps of Engineers' Report to the United States Congress on "National Program of Inspection of Dams" in May 1975.

The recommended guidelines were prepared with the help of engineers and scientists highly experienced in dam safety from many federal and state agencies, professional engineering organizations and private engineering consulting firms. Consequently, the evaluation criteria presented in the guidelines represent the comprehensive consensus of the engineering community.

Where necessary, the guidelines recommend a two-phased study procedure for investigating and evaluating existing dam conditions so deficiencies and hazardous conditions can be readily identified and corrected. The Phase I study is:

(1) a limited investigation to assess the general safety condition of the dam

(2) based upon an evaluation of the available data and a visual inspection

(3) performed to determine if any needed emergency measures and/or if additional studies, investigations and analyses are necessary or warranted

(4) not intended to include extensive explorations, analyses, or to provide detailed alternative correction recommendations.

The Phase II investigation includes all additional studies necessary to evaluate the safety of the dam. Included in Phase II, as required, should be additional visual inspections,

measurements, foundation exploration and testing, material testing, hydraulic and hydrologic analyses and structural stability analyses.

The authority for the Corps of Engineers to participate in the inspection of non-federally owned dams is limited to Phase I investigations with the exception of situations of extreme emergency. In these cases the Corps may proceed with Phase II studies but only to the extent needed to answer serious questions relating to dam safety that cannot be answered otherwise. The two phases of investigations outlined above are intended only to evaluate project safety and do not encompass in scope the engineering required to perform design or corrective modification work. Recommendations contained in this report may be for either Phase II safety analyses or detailed design study for corrective action.

The responsibility for implementation of these Phase I recommendations rests with the dam owner and the State of Montana, Department of Natural Resources and Conservation (DNRC). The owner is urged to contact the Montana DNRC prior to taking any action on report recommendations. It should be noted that nothing contained in the National Dam Inspection Act, and no action or failure to act under this Act, shall be construed (1) to create liability in the United States or its officers or employees for the recovery of damage caused by such action or failure to act or (2) to relieve an owner or operator of a dam of the legal duties, obligations, or liabilities incident to the ownership or operation of the dam.

The investigation process allows for report review by: the Montana DNRC and the Anaconda Copper Mining Company (owner/operator). Review comments are considered before final publication of the Phase I Inspection Report. Their written comments are enclosed in Appendix E.

1.1.2 Purpose and Inspection

The findings and recommendations in this report were based on visual inspection of the project, minimal field survey measurements, and review of available design and operation data. The purpose of the inspection is to make a general assessment as to the structural integrity and operational adequacy of the dam embankments and their appurtenant structures. Inspection procedures and criteria were those established by the Recommended Guidelines for Safety Inspection of Dams (Ref. 1).

The visual inspection of Silver Lake West Dam and Silver Lake East Dam was made on September 30, 1980. HKM Associates

personnel who attended the field inspection and contributed to this report were:

Dan Dyer, Geotechnical Engineer
Gary Elwell, Hydraulics/Hydrology
Mike Keene, Hydraulics/Hydrology, Team Leader

Other HKM personnel contributing to the report but not attending the field inspection were:

Dale R. Cunnington, Structural Engineer
Dan Nebel, Geology

Other personnel present during the September 30, 1980 inspection included:

Larry Tegg, Dam Safety Engineer, Montana DNRC, Dam Safety Section
Ron Eccleston, Water Supply Foreman, Anaconda Copper Mining Company
Charles Hill, Plant Coordinator, Anaconda Copper Mining Company

1.2 DESCRIPTION

1.2.1 General

Silver Lake is contained by two earth fill dams located in T5N, R13W, MPM, Deer Lodge County, Montana. Silver Lake West Dam is located in the SW 1/4 of Section 21 and Silver Lake East Dam is located in the SW 1/4 of Section 22 (Appendix A, Ref. 2 and 3). The dams and reservoir form an industrial water storage facility within the upper Columbia River Basin containing local runoff and water diverted from Storm Lake Creek, Twin Lakes Creek and Georgetown Lake. Outlet releases pass through a 45-inch pipe to Flint Creek and Georgetown Lake on the west, and through a 30-inch pipe, an aqueduct and natural streams to Anaconda on the east. There are no spillways.

The Anaconda Copper Mining Company owns and operates the project.

Of the two dams, Silver Lake East Dam will overtop first. It has a hydraulic height of 6.5 feet and impounds 17,920 acre-feet (AF) at the first overtopping dam crest elevation (elevation 6485.5 feet, see note on page x) (Ref. 4). The storage controlled by the east dam embankment is 2100 AF. The remaining storage is contained in the natural pool and can be released by pumping. Based on a visual reconnaissance and engineering judgment, at least three residences, as well as roads, bridges, and a small amount of agricultural land will be affected by a sudden breach of the east dam. A sudden breach of either dam could also jeopardize life downstream. The nearest downstream community is West Valley, which is located approximately 9 miles

east of the dam. On the basis of this information and in accordance with the Recommended Guidelines (Ref. 1), the project is classified intermediate in size and the downstream hazard potential is high (Category 1).

In the case of a failure of the west dam, there are at least three residences that could be impacted between Silver Lake and Georgetown Lake. Georgetown Lake is substantially larger than Silver Lake and could be expected to absorb a flood from a breach of Silver Lake West Dam.

The project was constructed to provide storage and regulation in support of industrial uses in the Anaconda area. Incidental benefits are provided for irrigation, municipal water supply, floodwater detention, recreation, and sediment accumulation. Storage to the normal pool level (elevation 6484.5 feet), is 17,570 AF. An additional 350 AF are available for flood surcharge storage between the normal pool level and the first overtopping east dam crest elevation for the project (6485.5 feet).

Silver Lake has a natural contributory drainage area of 1.9 square miles, but the major contributors of water are Storm Lake, Twin Lakes, and Georgetown Lake. The Silver Lake watershed is characterized by forested mountain terrain (Photo 1 of Appendix B). Elevations in the basin range from 7800 feet NGVD to about 6434 feet NGVD at the reservoir (Ref. 6).1/

1.2.2 Regional Geology

Silver Lake is situated in a shallow depression on the divide between the Flint Creek drainage to the west and Warm Springs Creek to the east. This divide also separates the Flint Creek Range to the north and the Anaconda Range to the south. Precambrian and Paleozoic sedimentary rocks form the core of the ranges with Tertiary igneous rocks intruded throughout the area. The Tertiary igneous rocks form dikes, sills, stocks, and batholiths. Structurally, the area is highly complex with two major structural elements apparently exercising control over the local structural development. The first of these, which passes about 30 miles north of the dam, is the Montana Linament. The second is the Perry Line located far to the south. Both seem to be primarily fault structured and form a triangular block 125 to 150 miles wide at its western base within Montana and 150 to 200 miles long, pointing eastward. Structures within this block are generally the result of eastward directed compression. Locally,

1/ Basin elevations in feet NGVD were obtained from the Silver Lake quad map. All other elevations contained in this report are local datum.

thrust faulting is common and generally follows a north-south alignment, paralleling the major Phillipsburg thrust about 10 miles to the west (Ref. 5).

1.2.3 Seismicity

Silver Lake is in a moderately active to active seismic zone with the majority of the region's seismic events occurring in the Southwestern Montana-Yellowstone Park area. Since 1925, Montana has experienced five shocks that reached intensity VIII or greater (Modified Mercalli Scale). The closest epicenter occurred at Helena, Montana which is approximately 65 miles northeast of the damsite. Numerous other shocks of intensity IV or greater have been reported within a 100-mile radius of the site (as of January 1974). The site is located in zone 3 of the Seismic Zone Map of Contiguous States, and it can be assumed that a major earthquake may occur within the life of the structure (Ref. 1, 6). Although the Zone Map is based on a known distribution of damaging earthquakes, it does not necessarily reflect accurate or adequate seismic design parameters for this site.

1.2.4 Local Geology

No on-site geologic reports or subsurface information for the dams is available. This section is based on geological and topographic map interpretation.

Silver Lake is situated in a shallow depression on the divide between the Flint Creek and Warm Springs Creek drainages. The lake is impounded by two shallow earth fill dams. The dams appear to be resting on shallow Quaternary alluvium which consists of coarse cobbles, gravels, and sands with little to no silts or clays. Scattered glacial deposits are present near the valley walls. The valley walls are formed of Paleozoic carbonates that have been intruded by Tertiary granodiorite. Structurally, the dams and lake lie on the south edge of a triangular fault-bounded block with a normal fault projecting through the lake and a normal fault projecting through the east dam. Numerous other small faults exist in the area. No recent fault activity has been noted in the area.

1.2.5 Design and Construction History

Silver Lake East Dam and Silver Lake West Dam were built by Anaconda Copper Mining Company. Available information indicates that the east dam was constructed in about 1918, and the west dam was originally constructed in about 1902 and later modified in about 1918. Only two drawings of the project were provided for review: Map of Silver Lake and Vicinity, dated January 1903; and Sketch Showing Proposed Dams at Silver Lake, dated August 1918.

Engineering, construction, and as-built drawings were not available for review. Other information such as soil test holes, soil test results for embankment design, embankment stability analysis data, construction quality control testing results, and construction inspection diaries was also not available.

Several years ago, the Montana Highway Department dumped additional rock riprap on the upstream face of Silver Lake East Dam; in particular, on the upstream face of the north one-half section of the dam. Evidently the Highway Department had some extra rock material from a local project, and Anaconda Copper Mining Company requested the material be placed on the upstream face of the dam to provide additional protection in combating wave erosion.

About five years ago, Anaconda Copper Mining Company replaced the walkway from the east dam to the pump station with an earth-fill spur dike. Also, as part of this same project, the old wood-stave pipe connecting the pump station to the steel outlet pipe was replaced with concrete pipe. The concrete pipe is embedded in the earthen spur dike.

Repair and maintenance records relative to the dam embankments are not available, primarily because major problems have not been experienced to date. Design, repair, and maintenance records relative to the Silver Lake and Georgetown Lake pump stations are described as being available but were not reviewed during this investigation.

CHAPTER 2
INSPECTION AND RECORDS EVALUATION

2.1 HYDRAULICS AND STRUCTURES

The hydraulics and structures evaluation included a review of available project data and a field inspection. Inspection photos are located in Appendix B, HKM drawings are provided in Appendix C and hydraulic rating information is shown in Exhibits D2 and D3.

2.1.1 Spillway

There are no spillways at Silver Lake West Dam or Silver Lake East Dam.

2.1.2 Outlet Works

There are two outlet works facilities located at Silver Lake. One is located at Silver Lake East Dam and the other is located at Silver Lake West Dam.

2.1.2.1 West Dam Outlet Works

The west dam outlet works is located approximately 117 feet from the right (north) abutment (Exhibit C2 of Appendix C). The outlet works facility consists of an inlet with trashrack and flow control gate, a 45-inch diameter pipe, an outlet, and a stilling pool.

The inlet is constructed from concrete and consists of a headwall and angled wingwalls. The pipe opening is protected by a trashrack constructed with vertical metal grating. A 45-inch diameter slidegate is used to regulate flow through the outlet works. The gate control wheel is located on a metal beam support which rests on top of the concrete inlet (Photos 2 and 3 of Appendix B).

The inlet and outlet structures are connected by a 45-inch diameter steel pipe with concrete encasement approximately 110 feet in length.

The outlet structure consists of a concrete headwall and angled wingwalls. The headwall extends 6 inches above the crown of the pipe. A concrete apron along the channel bottom forms the transition between the pipe outlet and a small stilling pool. The apron has a length of 6 to 8 feet. There is a small amount of riprap in the stilling pool. Banks along both sides of the stilling pool are very steep. The base width of the channel downstream of the stilling pool is about 20 feet. There is a major break in the channel slope below the stilling pool. The

slope downstream of the stilling pool is fairly steep (Photo 4 of Appendix B).

There is a small amount of deterioration on the concrete inlet (Photo 5 of Appendix B). There is also some bank erosion around the structure. A highwater mark is evident on the inlet approximately 24 inches below the top of the right wingwall and about 28 inches above the water surface at the time of the investigation. The slidegate was open a few inches on the day of the inspection. The slidegate was not operated, but the operator stated that the gate is fully operational and had been operated during the past summer.

A cursory inspection indicates the 45-inch pipe through the embankment is in good condition.

A small amount of concrete deterioration is present at the contact point between the pipe and the headwall at the outlet. Some chipping is present on the wingwalls. The steep banks along the stilling pool indicate some bank sloughing has taken place. Backcutting and erosion are present at the wingwalls. The channel banks downstream of the stilling pool have a good vegetative cover and appear to be stable.

It does not appear that bank sloughing in the stilling pool would reduce the outlet capacity. Access to the gate controls requires crossing a small timber bridge on the dam embankment. The bridge was apparently constructed to cross the pipe used to deliver water from Georgetown Lake to Silver Lake. The bridge is in poor condition, however, the east dam will overtop before the reservoir pool reaches the bridge level. Gate controls are locked.

Hydraulic rating information was not available. Therefore, new rating information was calculated assuming inlet control (Ref. 7). Inlet control was chosen because of the steep slope and relatively short length of the pipe, and the steep slope of the downstream channel. Outlet capacity is 120 cubic feet per second (cfs) at the normal pool level elevation of 6484.5 feet (see note on page x) and 130 cfs at the first overtopping east dam crest elevation of 6485.5 feet.

2.1.2.2 East Dam Outlet Works

The east dam outlet works is located about 540 feet from the left (north) abutment. The outlet works facility consists of a low level outlet and pump house, a high level outlet, a pipe network, and a return channel.

Operation of the low level outlet is dependent on pumping. The distance from the pump station floor to the bottom of the pump station is 85 feet. The pump columns are 83 feet long. There are 2-250 horsepower vertical turbine units in the pump station. The pumps were installed in about 1970. Two operating gates are located in the pump house immediately downstream of the pumps. The pump house is located at the end of a spur dike which extends into the reservoir pool (Photo 6 of Appendix B).

The high level outlet is located adjacent to the spur dike and the dam embankment. The inlet consists of a horizontal perforated inlet pipe connected to a vertical tower which contains a flow control gate. A manual control wheel for operating the gate is located on top of the tower (Photo 6 of Appendix B).

A pipe network transports and combines flows from the pump house and the high level outlet. The pipe network consists of: a 30-inch concrete pipe from the pump house to the junction of the two outlets; a 30-inch metal pipe from the high level outlet to the junction of the two outlets; an air-vacuum relief valve at the junction; and downstream of the junction, about 1200 feet of 30-inch diameter wood-stave pipe. Downstream of the wood-stave pipe water flows through approximately 300 feet of wood flume and then along the natural return channel until its confluence with Cable Creek (Photo 6 of Appendix B).

The gates in the pump station were not operated during the inspection, although the operator indicated the gates were fully operated as recently as July 1980. The gate is operated on a regular basis and a good seal of the gate is possible. The pumps have been in place for 10 years and appear to be in excellent condition. The interior of the pipe network was not inspected due to the extreme distance between the pipe outlet and the gate. The exterior of the wood-stave pipe appears to be in good condition.

The pipe outlet is far enough downstream that high discharges will not present a danger to the dam embankment. There does not appear to be any condition present that would reduce pipe discharge capability below the maximum discharge capability. It appears that high reservoir pool levels would not prevent access to the high and low level gate controls. All controls are locked. A switchover allows using Flint Creek power for the pumps if Bonneville power fails.

Outlet works hydraulic rating information is not available. The operator indicates the reservoir pool can be lowered about 25 inches in 24 hours using the pumps. For a representative high pool level, this drawdown is equivalent to an average discharge rate of about 350 cfs. Limited information was available for

calculating the high level outlet discharge capacity. The discharge capacity was estimated using the energy equation, and assuming a Mannings "n" of 0.013 and that the pipe flows full throughout its length. The discharge capacity is estimated to be 37 cfs to the normal pool level elevation 6484.5 feet (see note on page x) and 39 cfs to the first overtopping east dam crest elevation 6485.5 feet. It appears the high level outlet would not contribute significantly to outlet releases when the pumps are in operation.

2.1.3 Other Appurtenances

Other appurtenances at Silver Lake consist of a water supply system from Georgetown Lake at the west dam and water supply facilities from Twin Lakes and Storm Lake at the east dam.

A 30-inch steel pipe, approximately 2 miles long, is used to pump water from Georgetown Lake to Silver Lake. Flow controls are located at Georgetown Lake. The pipe extends about 50 feet into the reservoir pool and is supported by a metal framework where it extends over the reservoir (Photo 3 of Appendix B).

The exterior bituminous coating on the pipe is worn and deteriorating. Metal is exposed in several locations, however, the metal is in excellent condition. The metal support framework is deteriorating and some of the joints have come apart.

Water from Twin Lakes and Twin Lakes Creek is transported to Silver Lake through 1.2 miles of wood flume, 2 miles of asphalt-paved trapezoidal canal, and a 1250 foot wooden flume. The flume is supported above the ground by wooden supports and extends approximately 650 feet into the reservoir pool. Two wooden gates allow control over the flow in the flume. Water can be permitted to enter the reservoir or can be diverted to the east dam outlet pipe, therefore, bypassing the reservoir. It appears that little water could bypass the reservoir when the pumps are in operation. Flow through the system can also be controlled at Twin Lakes and at the diversion structure on Twin Lakes Creek (Photo 7 of Appendix B).

The Twin Lakes flume and canal appear to be in satisfactory condition.

Water is diverted to Silver Lake from Storm Lake and Storm Lake Creek through an earthen canal. Flow can be controlled at Storm Lake and at the diversion structure on Storm Lake Creek. A concrete control structure is located at the Silver Lake reservoir. Water enters the concrete structure and passes through a nydraulic jump to dissipate energy. Water then enters a stilling basin with a side overflow spillway. A slidegate is located on the far end of the stilling basin. Water passing

through the gate will flow by canal to the east outlet from the reservoir, completely bypassing Silver Lake. It appears little water could be bypassed with the east outlet works pumps in operation. Water passing over the side overflow spillway enters a natural channel and flows into Silver Lake. A wooden turnout structure for diverting water into Silver Lake is located just upstream of the concrete turnout (Photo 7 of Appendix B).

The supply canal from Storm Lake Creek appears to be in satisfactory condition and was operating on the day of the survey. The wooden turnout and the slidegate in the concrete stilling basin were not operated but appear functional.

There is a possibility for uncontrolled diversions to enter Silver Lake during flood conditions if the necessary measures, such as operating the required gates, are not completed.

2.1.4 Freeboard

Flood routing (Section 2.2.3) indicates the east dam overtops during the guidelines' (Ref. 1) recommended spillway design flood (which is the full PMF), and therefore, no freeboard exists for such conditions. The vertical distance from the normal pool level (elevation 6484.5 feet, see note on page x) to the first overtopping east dam crest elevation (6485.5 feet) is 1.0 foot. The selection of the normal pool level was based on remarks by the water supply foreman and physical evidence of reservoir pool levels. The water supply foreman estimated that a probable historic highwater elevation for Silver Lake is 6485.8 feet and stated that the dams have never been overtopped. The field survey indicates the first overtopping elevation is 6485.5 feet, therefore it is assumed that the probable highwater mark is about 6485.5 feet. The vertical distance between the reservoir pool and the first overtopping elevation at the time of the September 1980 field inspection was 3.4 feet.

Silver Lake is basically oriented in an east-west direction, with the dams on the east and west sides. The prevailing wind for this region is generally identified as being westerly (Ref. 8, 9). The reservoir location and orientation can be observed in Appendix A. Based on an effective fetch length of 1 mile, the minimum freeboard allowance should be about 4 feet (Ref. 10). The vertical distance between normal pool level and first overtopping dam crest elevation is insufficient to prevent overtopping by wind-generated waves at either dam.

2.2 HYDROLOGY

2.2.1 Physiography and Climatology

Silver Lake has a 1.9-square mile catchment area. The catchment area can be divided into 3 subareas: first is an area 0.4 square

mile located north of Silver Lake; second is an area of 1.0 square mile located south of Silver Lake, and last is the 0.5 square mile area of Silver Lake at its normal pool level. The two non-reservoir areas are irregular in shape (Appendix A). The topography is comprised of forested mountain terrain, although dirt roads and a small timber cut area are present in the catcnment area. The catchment area is a quick response watershed.

Soils in the Silver Lake drainage area consist of two types:

(1) Cold loamy forested soils on glacial moraines which are "areas dominated by light colored, deep, loamy soils with gravelly subsoil and substratum on slopes up to thirty five percent." (Ref. 11)

(2) Cold loamy soils on metamorphic bedrock which are "areas dominated by light colored, deep loamy soils with gravelly subsoil and substratum." "Slopes are dominantly steep to very steep." (Ref. 11)

The climate of the region may be classifed as modified continental, occasionally reflecting tendencies to be similar to higher elevation Pacific slope climates. This area exhibits marked seasonal variations in climate, with differences in distribution of monthly average precipitation between mountain and valley areas. Specific to the moisture-runoff characteristics of the Silver Lake basin, runoff is derived chiefly from melting snow. In general, the valleys are relatively dry during the colder months and wet during the late spring and early summer. The wettest part of the year in the mountains is generally from midwinter to early spring. The average annual precipitation for the climatological station at Silver Lake is 18.8 inches.

Average annual temperature for East Anaconda, about 14 miles east of Silver Lake, is 42 degrees F. Winters are typically cold, with January being the coldest month. The monthly average temperature for January in East Anaconda is 22 degrees F. Summers, although fairly warm, seldom produce oppressive heat. Even the warmest summer days are followed by pleasantly cool nights. July is commonly the warmest month of the year for this region, with average monthly temperatures of 66 degrees F. at East Anaconda. The average number of days between the last recording of 32 degrees F. in the spring and the first in the fall is about 110 at East Anaconda (Ref. 8 and 9).

No natural streamflow measurements are available in the area.

2.2.2 Estimated Probable Maximum Flood (PMF)

The probable maximum precipitation (PMP) and the estimated probable maximum flood were developed for the Silver Lake drainage basin. The ratio of the reservoir area to the non-reservoir area is greater than 25 percent, therefore the two areas are separated for the purpose of this analysis. The PMF is the flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the study region.

Silver Lake is located west of the Continental Divide, and hence, general storm and thunderstorm PMP values were calculated using procedures contained in the National Weather Service's Hydrometeorological Report No. 43 as updated by the 1967 memo (Ref. 12). Snowmelt was estimated based on techniques in HMR 43 and "Runoff from Snowmelt" by the U.S. Army Corps of Engineers (Ref. 13). The thunderstorm PMP was assumed to be a critical event because the total runoff volume for the thunderstorm was significantly greater than for the first six hours of the general storm with snowmelt and during an event as short as the thunderstorm, the water supply foreman may not be able to open the bypass and outlet gates and close the inflow gates to pass the flood runoff. Thunderstorm PMP values for durations up to 6 hours were estimated using HMR 43. The 1967 memo allows for some reduction of the PMP that was not originally contained in HMR 43. The 1/2 hour, 1-hour, 3-hour, and 6-hour precipitations are 5.9, 8.0, 9.5, and 9.7 inches, respectively. It was found that the highest thunderstorm PMP value occurs during the month of August. Subdivision of the calculated rainfall increments was required to provide compatibility with the duration of the unit hydrograph. A 3-minute unit hydrograph was selected for Silver Lake using criteria presented in the SCS Hydrology Handbook (Ref. 14). The August PMP storm was plotted in the form of a depth-duration curve for convenience in selecting incremental rainfall values. The 3-minute August PMP values were ordered according to the reverse pattern of the unit hydrograph ordinates.

It is assumed that the PMP storm can be preceeded by another relatively severe storm that could cause a saturated soil condition. However, there is still potential for minimum retention losses to the soil. Therefore, a loss rate of 0.08 inches/hour, based on minimum loss rates for soils such as those found in the basin, was used in the computations.

The runoff condition, or PMF, resulting from an August PMP thunderstorm was estimated using the PMP values and the unit hydrograph approach. A 3-minute unit hydrograph was developed for the Silver Lake basin using the SCS method (Ref. 14) and the U.S. Army Corps of Engineers' computer program HEC-1 (Ref. 15). The resultant August PMF has a total runoff volume of 958 AF.

2.2.3 Flood Routing

The PMF was routed through Silver Lake using the computer program HEC-1 (Ref. 15). It is assumed that uncontrolled inflow from the Storm Lake and Twin Lakes diversions during flood conditions would be insignificant relative to the PMF. It was also felt that it would not be reasonable to include water from the diversions when considering the low percentage of the PMF hydrograph ordinates controlled by the dams without including the diversions. Runoff from an antecedent storm was not specifically considered due to the low percentage of the PMF hydrograph ordinates controlled by the dams when starting the routing at the normal pool elevation (elevation 6484.5 feet, see note on page x); however, it appears reasonable to assume the initial reservoir level prior to routing the PMF is at the normal pool level. The support rationale for this assumption is that the water users would prefer to store as much water as possible in preparation for irrigation, municipal, and industrial uses.

Reservoir area-capacity-elevation data and outlet works hydraulic rating data were not available. Area-capacity-elevation information was obtained by planimetering a contour map from the project file (Ref. 4). It was necessary to extrapolate the area-capacity curves above elevation 6480 feet. Sediment is not a significant factor at Silver Lake, and it is assumed that the storage capacity has not changed substantially due to sediment accumulation. There are no unregulated outlet facilities at Silver Lake. For routing purposes it was assumed that all outlet facilities would be closed or nearly closed. Due to the quick response nature of the watershed it is reasonable to assume there would not be time to open the outlet gates.

For the purposes of flood routing and according to Phase I investigation criteria, the minimum dam crest elevation is the elevation at which overtopping of one or both of the dams will occur. This criteria assumes overtopping and failure of embankment-type dams to be coincidental. Based upon the embankment profiles surveyed on September 30, 1980 (Exhibits C5 and C6 of Appendix C), first overtopping will occur at the east dam at an elevation of 6485.5 feet.

Routings were made of lesser hypothetical floods than the PMF to determine the magnitude of floods the dam can contain. The hypothetical hydrographs are obtained by applying percentages to the PMF ordinates. A flood with a hydrograph having ordinates corresponding to 37 percent PMF ordinates is just controlled by the project. Larger floods would overtop the dam.

2.3 GEOTECHNICAL EVALUATION

The geotechnical evaluation of Silver Lake East and Silver Lake West Dams included a field inspection and a search and review of

project data. The field inspection consisted of photograph documentation, a dam crest profile survey, slope stability observations of the dam embankment, seepage observation, and measurements of the slope angles for each dam. Inspection photos are included in Appendix B, sketches of the plan view of the dams are included in Exhibits C1 and C2 of Appendix C, sketches of the typical embankment cross sections are shown in Exhibits C3 and C4, and the crest profile surveys are shown in Exhibits C5 and C6. Results of the slope angle measurements are provided in Exhibits C1 and C2.

2.3.1 Dam Embankments

Although Silver Lake is a natural lake, dam embankments have been constructed at both the east and west ends of the lake to raise the water level. Both dams are earth fill structures which were designed and constructed by the Anaconda Copper Mining Company.

Design drawings (Ref. 4) prepared by the Anaconda Copper Mining Company indicate an embankment configuration for each of these dams, however, the actual embankment configuration varies. The crest control for both embankments is designed to be at elevation 6489 feet. A description of the embankment materials is not available.

2.3.1.1 Silver Lake East Dam

The available drawings of Silver Lake East Dam suggest that the dam was constructed in about 1918 (Ref. 4). The embankment has an estimated maximum structural height above the deepest point on the foundation surface of about 11 feet (Photo 8 of Appendix B) and a crest length of approximately 1012 feet. There is a second earth fill embankment (spur dike) extending from the dam into the lake over the outlet works. As the condition of this spur dike is not critical to the stability of the dam and its purpose is not to retain water, it will not be described in detail in this report.

The survey for Silver Lake East Dam embankment profile, shown on Exhibit C5 of Appendix C, shows the crest elevation varies about six (6) feet from one abutment to the other. The high abutment (north end) appears to be the result of road fill. The lowest point on the crest is at the south abutment, elevation 6485.5 feet. This elevation is 3.5 feet below the design dam crest control elevation. The construction drawings (Ref. 4) indicate the lower abutment was designed with a 3.5 foot drop at the abutment contact. The reason for this drop is unknown.

The crest design width was 10 feet. Field measurements indicate the crest width varies from 12 to 25 feet. According to the water supply foreman, the additional crest width is the result of

the Montana Highway Department maintenance crews dumping loose rock on the upstream face of the embankment. This additional loose rock is slough which has fallen from hillside cuts adjacent to the highway in the vicinity of Silver Lake. The dumped rock is located only on the north one-half of the dam (Photos 9 and 10 of Appendix B).

The upstream slope of the embankment was designed with a slope of 1V on 2.5H. The existing slope varies from 21 to 29 degrees or from 1V on 2.5H to about 1V on 1.8H as shown on Exhibit C3. The steeper parts of the slope are the result of the dumped loose rock previously described (Photo 10 of Appendix B). The flatter parts of the slope are on the embankment south of the spur dike (Photo 11 of Appendix B).

There is no vegetation on the upstream face of the embankment north of the spur (Photo 9 of Appendix B). South of the spur there is a sparse to moderate cover of natural grasses, weeds, and bushes, and about 7 relatively large pine trees above the normal water surface (Photo 12). Debris on the upstream slope is limited to very small material (Photo 10 of Appendix B).

The downstream face of the dam was designed with a slope of 1V on 2H. Field measures of 27 to 31 degrees or 1V on 1.7H to 1V on 2.0H were determined as shown on Exhibit C3 (Photo 8 of Appendix B). Burrowing animal holes are evident on the downstream face, but they do not create a safety problem. This slope has a moderate to dense cover of natural grasses, weeds, brush, and some trees (Photos 8 and 12 of Appendix B).

2.3.1.2 Silver Lake West Dam

The actual construction dates of Silver Lake West Dam are unknown, however, the available information suggests the dam was constructed originally in about 1902 and raised in about 1918. A topographic drawing prepared by the Anaconda Copper Mining Company in January 1903 shows location of the embankment, suggesting it may have been constructed prior to the drawing date (Ref. 4). A sketch by the Anaconda Copper Mining Company dated August 2, 1918 shows a single cross section of the embankment and the ground profile along the dam. The cross section includes proposed grade lines for raising the embankment to elevation 6489 feet. According to this information, the original embankment was constructed to elevation 6484 feet, then raised to elevation 6489 feet.

Based on visual inspection, the maximum structural height of the existing dam above the deepest point on the foundation surface is about 17 feet (Photo 13 of Appendix B) and the total crest length is approximately 1292 feet. The crest length includes a bridge about 20 feet wide located as shown on Exhibit C2. The dam crest

width was designed to be 12 feet. The measured crest width varies from 15 to 20 feet (Photo 14 of Appendix B). The variable crest width appears to be the result of poor construction control and grading of the gravel road across the crest. Erosion on the upstream face may also contribute to the variability.

The crest profile survey of Silver Lake West Dam shows the maximum differential elevation is about 3.2 feet (Exhibit C6 of Appendix C). There is a slight depression at the maximum dam section, elevation 5486.6 feet, suggesting slightly over 2 feet of settlement may have occurred in the embankment and foundation soils. This apparent settlement has not caused significant structural damage. There are also several depressions on the crest of the embankment caused by ponded water and vehicular traffic.

The upstream embankment slope was designed with a slope of 1V on 1.5H. A small berm located near the normal water surface is shown on the drawing with a flatter slope below the berm. It is assumed that the berm and flatter slope are the result of wave action and not part of the design.

The existing upstream face has slopes varying from near vertical near the crest to about 27 degrees as shown in Exhibit C4 of Appendix C (Photo 14 of Appendix B). The slope appears to vary primarily as a result of erosion due to wave action.

There is a protective loose rock riprap blanket on most of the upstream face (Photos 14 and 15 of Appendix B). This material appears to have been placed in recent years (within 15 years--estimate based on the age of trees growing in the riprap), as old erosion scars are evident under the riprap; some riprap has been hand-placed at near vertical angles, suggesting erosion had occurred prior to placement of the riprap. There is a moderate cover of grass, weeds, willows, and other trees growing above the normal water surface on the upstream face (Photo 15 of Appendix B).

The downstream face was designed with a slope of 1V on 1.5H. The existing downstream face of the dam has a slope of from 35 to 27 degrees (average slope of about 1V on 1.7H) as shown on Exhibit C4 of Appendix C. It appears that a layer of topsoil has been placed on the downstream slope in the area of the maximum section. It is assumed that topsoil has not been placed over the entire downstream slope. There is a moderate to heavy cover of natural grasses, weeds, and trees on the downstream slope (Photo 16 of Appendix B).

2.3.2 Foundation Conditions and Seepage Control

Foundation

No records of test holes are available for either dam. Apparently no soil tests were performed during the design of either embankment.

The foundation conditions under the dams are unknown. Based on geologic features and visual inspection of the topography at the embankment locations, it is likely that both dams are resting on shallow alluvial deposits of sand and gravel with minor amounts of silt and clay size soils.

Seepage

According to the drawing by the Anaconda Copper Mining Company (Ref. 4) there is no cutoff trench or seepage control drain system under either dam. At the time of the September 1980 field investigation, Silver Lake was at elevation 6482.2 feet. Considerable seepage was observed at both dams.

Water was seeping through the Silver Lake East Dam embankment and exiting on the downstream slope near elevation 6481 feet. The condition indicates that the hydraulic gradient through the embankment is relatively flat. A large pool of seepage water has accumulated immediately downstream from the embankment as located on Exhibit C1 of Appendix C (Photo 8 of Appendix B). Surface flows from this seepage pool were estimated during the field investigation to be between 50 and 100 gallons per minute.

Near the maximum section of Silver Lake West Dam, seepage water was saturating the downstream embankment at the estimated elevation of 6478 feet. Two large seepage areas were observed and are indicated on Exhibit C2 (Photos 13 and 16 of Appendix B). The areas were identified by standing water and saturated embankment soils.

In conclusion, seepage is a major problem at both dams. Ponded seepage water below both dams creates saturated foundation soil conditions and there is a high phreatic surface through the embankments. Apparently there are no seepage control systems and the natural foundation and embankment soils are relatively pervious.

2.3.3 Stability

The slope angles measured during the field investigation are shown in Exhibit C1 and C2 of Appendix C. These angles were measured with an Abney Level and should be considered approximate.

There is no stability analysis data available to evaluate the slope design for either dam. Apparently no soil strength tests were performed and stability calculations were not made. The embankment materials are unknown. Observations of surface materials on the downstream face suggest the embankment materials may be gravelly clay.

Small erosion gullies were observed on both the upstream and downstream faces of both dams. These gullies are concentrated on Silver Lake West Dam at points where ponded water on the crest spills over the embankment slope (Photo 17 of Appendix B). Presently, these gullies do not create a safety hazard.

The reservoir shorelines are considered to be in stable condition as no major slides or scarpments were observed. The shoreline is occasionally vertical, or near vertical, to heights of about 3.5 feet and localized sloughing occurs due to wave action and saturated conditions.

2.3.3.1 Embankment - Silver Lake East Dam

Silver Lake East Dam is low, having an assumed maximum structural height of 11 feet. The downstream slope is about 1V on 2H. There was a high phreatic surface through the embankment and the seepage quantities were high. Some minor topsoil sloughing is evident on the downstream face, but this sloughing does not presently create a safety hazard. Seepage water emerging at the downstream toe was clear suggesting there is no soil piping. Except for this high phreatic surface and the large seepage quantities through the dam there are no outward signs of potential instability. However, because of the steep downstream slope combined with the high seepage path, the downstream embankment slope stability probably does not conform to criteria in the recommended guidelines.

2.3.3.2 Embankment - Silver Lake West Dam

Small scarps are evident on the downstream face at several locations where topsoil has sloughed (Photo 16 of Appendix B). Most of the sloughing occurs on the lower portions of the embankment where the soils are saturated. The depth of the slough material is estimated to be less than 1.5 feet. This condition is not considered to be of immediate danger. Topsoil sloughing may develop into a stability and/or erosion problem in time.

The downstream slope below about elevation 6478 feet was saturated as a result of seepage through the dam. The face is at slopes of from 1V on 2H to 1V on 1.4H. Based on these conditions, it is believed that the stability of the embankment does not conform to criteria in the Recommended Guidelines.

The embankment material/structural backfill of the outlet structure has experienced some erosion (Photo 3 of Appendix B). The concrete structure is not undercut, but without riprap protection erosion will continue and the structure may be undercut and damaged.

2.3.4 Rock Riprap

Loose rock riprap has been placed on part of the upstream face of both dams (Photos 9, 10, 14 and 15 of Appendix B). This rock is generally argillaceous limestone with some partially metamorphosed mudstone and siltstone.

There is a minor amount of rock riprap on the south half of Silver Lake East Dam (Photo 11 of Appendix B). However, this part of the dam has not been damaged significantly by wave action because wave build-up is hampered by the earth fill spur and a wooden flume. If the wooden flume were removed, riprap protection on the south end of the embankment would be inadequate.

The north end of Silver Lake East Dam has a thick nonuniform cover of riprap which has been dumped on the face by the Montana Highway Department maintenance crews. The dumped rock is accumulations of slough from highway cut sections. This material provides a good protective cover but it has not been spread uniformly over the face. The average rock size is near 6 inches and the maximum size is about 3 feet. Many surface irregularities are evident (Photo 10 of Appendix B). In summary, riprap protection on Silver Lake East Dam presently appears adequate.

The riprap on the upstream face of Silver Lake West Dam is generally inadequate. At one location near the right (north) abutment, at the corner where the dam axis extends easterly toward the lake, wave action has cut the embankment to a vertical height of about 3 feet. At the maximum section of the embankment, the riprap protection appears adequate (Photo 15 of Appendix B). The nominal rock size is about 8 inches and the rock quality is good. The riprap has occasionally slipped down the slope due to erosion and wave action.

Near the outlet works of Silver Lake West Dam, right abutment, some erosion protection is provided by gravel but this protection is inadequate. There is no riprap protection.

2.4 PROJECT OPERATION AND MAINTENANCE

Silver Lake East Dam and Silver Lake West Dam are owned and operated by Anaconda Copper Mining Company. The primary purpose for stored water in Silver Lake is industrial water supply for

the mining operation, with secondary benefits for irrigation, municipal water supply, recreation, sediment accumulation, and flood control. The project has a general operation plan which is dictated by storage conditions in Silver Lake, Storm Lake, and Twin Lakes; seasonal water requirements; and flood potential. However, there is no written operation plan. Also, seasons of the year play an important part in the operation plan. Operation records are kept on inflow to Silver Lake from Storm Lake and Twin Lakes. Also, daily pool level measurements are made at Silver Lake. A more detailed discussion of project operation and maintenance is provided below.

2.4.1 Silver Lake Supply

There are four primary sources of water supply to Silver Lake, which include: diversion of natural overflow from the high mountain storage facilities of Twin Lakes and Storm Lake, and diversion of natural runoff from the drainage area between the high mountain lakes and the diversion points; regulation and diversion of water stored in Twin Lakes and Storm Lake; reregulated water from Georgetown Lake; and natural, local runoff.

In general, the high mountain storage facilities of Twin Lakes and Storm Lake fill and exceed their normal storage capacity each year in the spring and early summer due to snowmelt runoff and rainfall runoff. The spillways are unregulated for both storage facilities, and hence, the excess runoff is spilled downstream. These releases are combined with natural runoff being generated by the snowmelt/rainfall process on drainage areas downstream of the high mountain storage facilities. The combined runoff can be, and generally is, diverted to Silver Lake utilizing diversion structures and delivery systems. This is the primary source of inflow to Silver Lake during the spring and summer months.

Twin Lakes and Storm Lake provide storage water for Silver Lake later in the year as well. In particular, the low-level outlets at the high mountain lakes are opened in the fall of the year and stored water is released downstream on an "as needed" basis for diversion to Silver Lake.

The third source of water supply to Silver Lake is reregulated water from Georgetown Lake. During the summer and fall, Silver Lake water is released and transported to Georgetown Lake by a gravity feed system. Starting in December and continuing until the early spring, Georgetown Lake water is pumped back to Silver Lake.

Natural, local runoff to Silver Lake is also a supply source. This localized runoff is small in comparison to the other sources because the natural contributory drainage basin amounts to only

1.9 square miles. Local runoff occurs in response to snowmelt and general, relatively long-duration rainstorms in the spring and early summer. There is some contribution during summertime thunderstorm activity.

2.4.2 Silver Lake Releases

Releases from Silver Lake can be made from either the east or the west side. Timing of releases is dictated by such things as downstream use requirements, downstream flood potential and flooding potential at Silver Lake, season of the year, etc. Also considered in the operation of Silver Lake is the lowering of the pool to reduce freeze potential of some outflow components. On the east side, releases can be made either by gravity or pumping (See Section 2.1.2.2). The releases on the east side provide water for the mining operation in Anaconda, a small amount of irrigation, domestic usage, and recreation.

Releases on the west side are made primarily for reregulation purposes. Silver Lake water is released through a headgate structure (Section 2.1.2.1) and gravity fed to Georgetown Lake. These releases are made not only to maximize storage availability at Silver Lake during the spring-early summer season, but also to lower the Silver Lake pool to eliminate freeze potential along the outflow pipe on the east side.

2.4.3 Silver Lake Measurements

Pool level readings of Silver Lake are made on a daily basis by the water supply foreman. Diverted water from the Twin Lakes and Silver Lake supply is monitored on a seasonal, but regular basis by the water supply foreman. Records are kept and are available for review in the Anaconda Company office or in the water supply foreman's office near Silver Lake East Dam.

2.4.4 Silver Lake Inspections

The plant coordinator for Anaconda Copper Mining Company performs a general inspection of the total project at least once monthly. The water supply foreman monitors the project on a daily basis. More specifically, the foreman takes measurements as described in Section 2.4.3, takes measurements as necessary on reregulation storage facilities, and checks the operation of Silver Lake appurtenances.

2.4.5 Silver Lake Maintenance

Major maintenance or repair on Silver Lake dams or appurtenances is performed as needed. Some regular maintenance is required on certain mechanical components of the project, but in general, the plant coordinator and water supply foreman indicate that only

minimal maintenance/repair work has been required in the past. Periodically rock riprap is dumped on the upstream face of the east dam to protect against wave erosion. Specific modifications to the project are described in Section 1.2.5.

2.4.6 Silver Lake Warning Plan

There is no formal plan of action in the event of dam distress. Though not part of a formal plan, a distress condition would be communicated by phone, radios, and door-to-door contact.

CHAPTER 3
FINDINGS AND RECOMMENDATIONS

3.1 FINDINGS

Visual inspection of the dam, supplemented by analysis of the project in accordance with the guidelines (Ref. 1) and the contract performance standards, resulted in the following findings.

3.1.1 Size, Hazard Classification and Safety Evaluation

In accordance with the inspection guidelines (Ref. 1), both Silver Lake West Dam and Silver Lake East Dam are classified as intermediate in size and, based on our visual inspection and engineering judgment, have a high downstream hazard potential. Therefore, the guidelines' recommended spillway design flood (SDF) for this project is 100 percent of the PMF. Based on reconnaissance level investigations, the project is incapable of handling the recommended SDF without overtopping and causing the east dam (which will overtop first) and possibly the west dam to fail which, in our judgment, could jeopardize life and property downstream. Silver Lake Dam Project does not conform to the recommended guidelines.

3.1.2.1 Dam Embankment - Silver Lake East Dam

Except for the high seepage path through the embankment and the large seepage quantities, Silver Lake East Dam appears to be stable. However, because of the seepage and related potential problems such as soil piping, sloughing, and erosion, the stability of the downstream embankment probably does not conform to criteria in the Recommended Guidelines. Piping was not observed. Apparently there is no seepage control system. Settlement does not seem to be a problem. The embankment materials are unknown. Burrowing animal holes are evident on the downstream face and large pine trees are growing near the embankment crest.

3.1.2.2 Dam Embankment - Silver Lake West Dam

The stability of the Silver Lake West Dam embankment does not appear to meet criteria in the Recommended Guidelines. Seepage through the embankment is evident as a portion of the downstream slope is saturated and there is standing seepage water at the toe of the embankment. The embankment slopes are relatively steep and some settlement of the embankment is apparent. Topsoil on the downstream slope is sloughing. There is a lack of riprap at some locations and there are depressions on the crest of the dam caused by ponded water and vehicular traffic.

3.1.3 Spillway

There are no spillways at Silver Lake East Dam or Silver Lake West Dam.

3.1.4 Outlet Works

There are two outlet works facilities at Silver Lake, one at the west dam and the second at the east dam.

3.1.4.1 West Dam Outlet Works

The outlet works facility at the west dam appears to be in satisfactory operating condition. There is concrete deterioration present at the inlet. Bank erosion is also evident around the inlet. Concrete deterioration is also present at the outlet. Specifically, deterioration is occurring on the wingwalls, and at the contact point between the headwall and the pipe. Backcutting and erosion is also present at the downstream wingwalls, however, this does not endanger the dam at this time. Sloughing has occurred along the banks of the stilling pool, however, the channel banks downstream of the pool have a good vegetative cover and appear stable. The small timber bridge, located on the west dam embankment that provides access to the outlet gate controls is in poor condition. The west outlet works has a discharge capacity of 120 and 130 cfs to the normal pool elevation 6484.5 feet (see note on page x) and the first overtopping east dam crest elevation 6485.5 feet, respectively.

3.1.4.2 East Dam Outlet Works

The outlet works facilities located at the east end of Silver Lake also appears to be in satisfactory condition. The pumps, which permit low level releases, are just 10 years old and appear to be in good condition. The interior of the oulet pipes could not be inspected due to the long length, although the exterior of the wood-stave pipe appeared to be in reasonably good condition. Based on the information from the operator, the discharge capacity of the pumps is estimated to be 350 cfs for a representative high reservoir pool level. Discharge capacity of the high level outlet is 37 and 39 cfs to the normal pool elevation 6484.5 feet (see note on page x) and the first overtopping east dam crest elevation 6485.5 feet, respectively.

3.1.5 Operation and Maintenance

There is a general operation plan which is dictated by storage conditions and flood potential at Silver Lake and supporting projects, and seasonal water requirements. Major support facilities which are part of the storage-regulation-reregulation

plan are: Twin Lakes; Storm Lake; diversion and transportation facilities for Twin Lakes and Storm Lake water; Georgetown Lake; and pumping plant and transportation facilities for reregulated water from Georgetown Lake. Records of diverted flows to Silver Lake, and Silver Lake pool levels, are maintained by the water supply foreman.

General-type inspections of the total project are made on a regular basis by the Anaconda Copper Mining Company plant coordinator and water supply foreman. The water supply foreman lives immediately downstream of Silver Lake East Dam, and visits the dams and support facilities regularly. Historically, major repairs have not been required on the project. Regular maintenance is performed by the water supply foreman or other Anaconda Copper Mining Company employees on certain mechanical components of the project.

A warning plan to alert downstream inhabitants of dam distress has not been developed.

3.1.6 Other Appurtenances

A cursory review was made of the water supply systems from Storm Lake, Twin Lakes, and Georgetown Lake. The supply systems appear to be in satisfactory condition, with the exception of deterioration of the bituminous coating and metal pipe supports on the pipe from Georgetown Lake.

3.2 RECOMMENDATIONS

(1) Immediately develop, implement, and periodically test an emergency warning plan for use in the event of distress at the east and/or west dam.

(2) Raise the dam embankments in low areas and/or lower the normal pool level to provide adequate vertical distance between the normal pool level and the first overtopping dam crest elevation for wave runup.

Using suitable material, fill and properly compact all localized depressions along the dam crests related to traffic damage.

(3) Perform the following repairs on the west dam outlet works: repair concrete deterioration at the inlet and outlet, and make the necessary repairs to stabilize the banks in the stilling pool downstream of the pipe outlet.

(4) Replace/rearrange rock riprap along the upstream face of the Silver Lake West Dam embankment where the rock has moved downslope or is deficient. Also, place riprap protection around the Silver Lake West Dam outlet structure to check erosion.

(5) Repair the small timber bridge on the west dam embankment that provides access to the outlet gate controls.

(6) Inspect all conduits passing through the embankment and repair as needed.

(7) Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required storage/outflow capacity and modify the project as studies indicate.

(8) Consider building an uncontrolled spillway to provide a more positive control on the maximum operating lake level.

(9) Have a qualified geotechnical engineer evaluate both dam embankments for stability and seepage using recommended guideline criteria. Assessment of the phreatic surface through the dams may be based on piezometer readings or observed embankment seepage conditions obtained during a sustained high pool period. Place a record of this evaluation on file. Modify the dam sections as required for stability.

(10) Conduct periodic inspections of both dams by qualified engineers at least once every five years. Include an inspection of all conduits through the embankments in this program.

(11) Develop a comprehensive operations and maintenance plan. The plan should insure water cannot be stored above a maximum operating level established by considering wave runup and flood handling capability.

Contact the Montana DNRC, Dam Safety Section, prior to performing any remedial construction to insure compliance with all pertinent laws and regulations.

REFERENCES

1. U.S. Army Corps of Engineers, Office of the Chief of Engineers Report to the U.S. Congress, National Program of Inspection of Dams, Vol. 1, Appendix D., "Recommended Guidelines for Safety Inspection of Dams". Washington, D.C., Department of the Army, May 1975.

2. U.S. Geological Survey, 7-1/2 Minute Quad Map, Silver Lake, Montana 1971.

3. U.S. Geological Survey, Butte, Montana, AMS, Scale 1:250,000, 1954.

4. Anaconda Copper Mining Company, Silver Lake Project Files.

5. Earll, F.M., Mines and Mineral Deposits of the Southern Flint Creek Range, Montana, Montana Bureau of Mines and Geology, Bulletin 84, 1972.

6. Von Hake, C.A., Earthquake Information Bulletin, USGS, Vol. 10, No. 4, 1978.

7. Montana Department of Highways, Hydraulics Manual, Helena, Mt.

8. National Oceanic and Atmospheric Administration, Climatological Data, Montana, National Climatic Center, Asheville, N.C.

9. National Oceanic and Atmospheric Administration, Climates of the States, Volume II, "Western States Including Alaska and Hawaii", Port Washington, N.Y., 1974.

10. U.S. Bureau of Reclamation, Design of Small Dams, 2nd. Edition, 1973, Revised Reprint, 1974.

11. State of Montana, Comprehensive Area-Wide Water and Sewer Plan 1970, Volume 12, Deer Lodge and Silver Bow Counties, 1970.

12. National Weather Service, Hydrometeorological Report No. 43, Probable Maximum Precipitation, Northwest States, Washington, D.C., 1966.

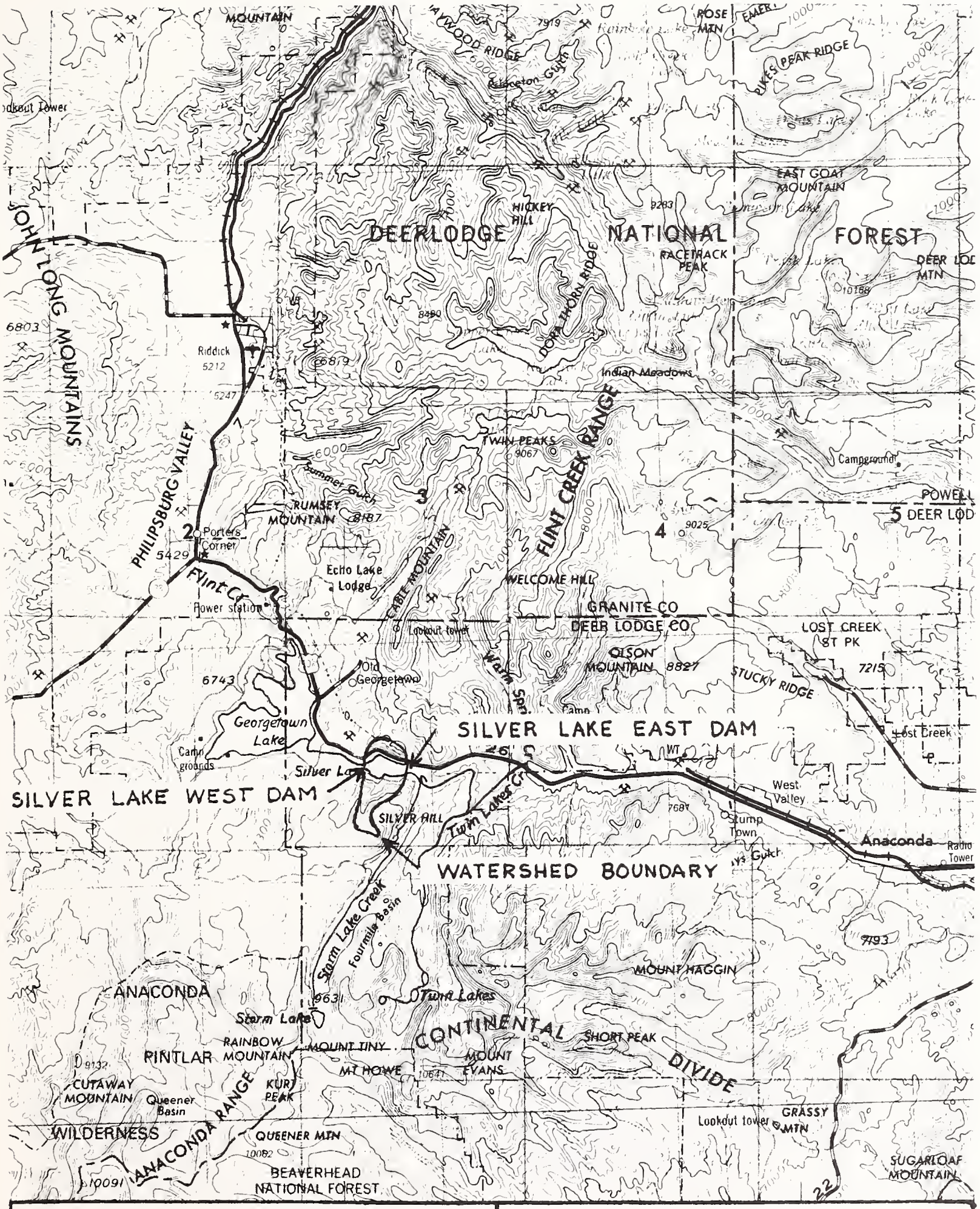
13. U.S. Army Corps of Engineers, Runoff from Snowmelt, EM 1110-2-1406, 1960.

14. U.S. Soil Conservation Service, National Engineering Handbook, Section 4, "Hydrology", Washington, D.C., 1969.

15. U.S. Army Corps of Engineers, Hydrologic Engineering Center, HEC-1 Flood Hydrograph Package, Davis, California, September, 1978.

APPENDIX A

VICINITY & WATERSHED MAP



SOURCE: BUTTE, MT. AMS MAP, USGS

APPENDIX A

VICINITY & WATERSHED MAP

SILVER LAKE EAST DAM &
SILVER LAKE WEST DAM

APPENDIX B

INSPECTION PHOTOS

Photo No. 1 - Drainage Basin.
The drainage basin consists of forested mountain terrain.

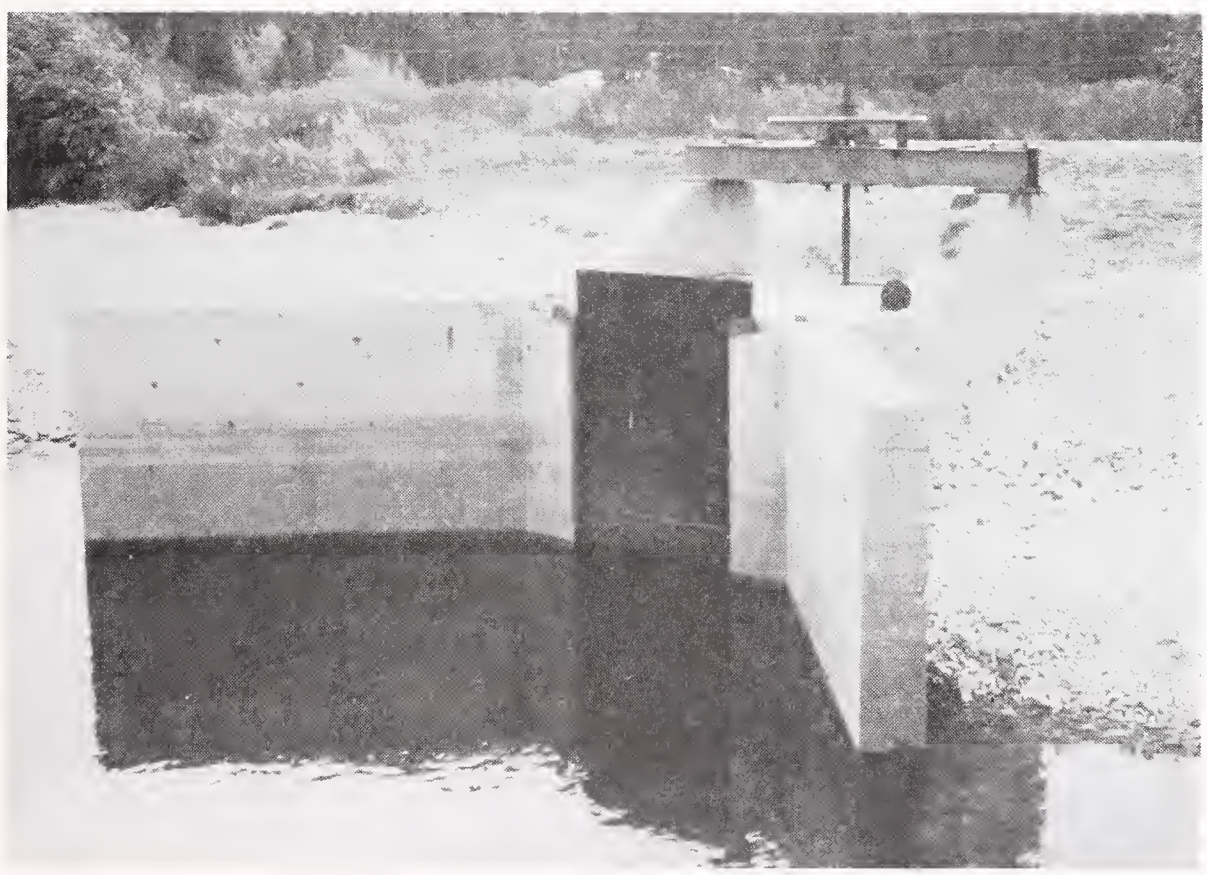


Photo No. 2 - Outlet Works.
Shown is the inlet of the west dam outlet works. A vertical metal grating protects the pipe inlet. High water marks are present on the wingwalls.

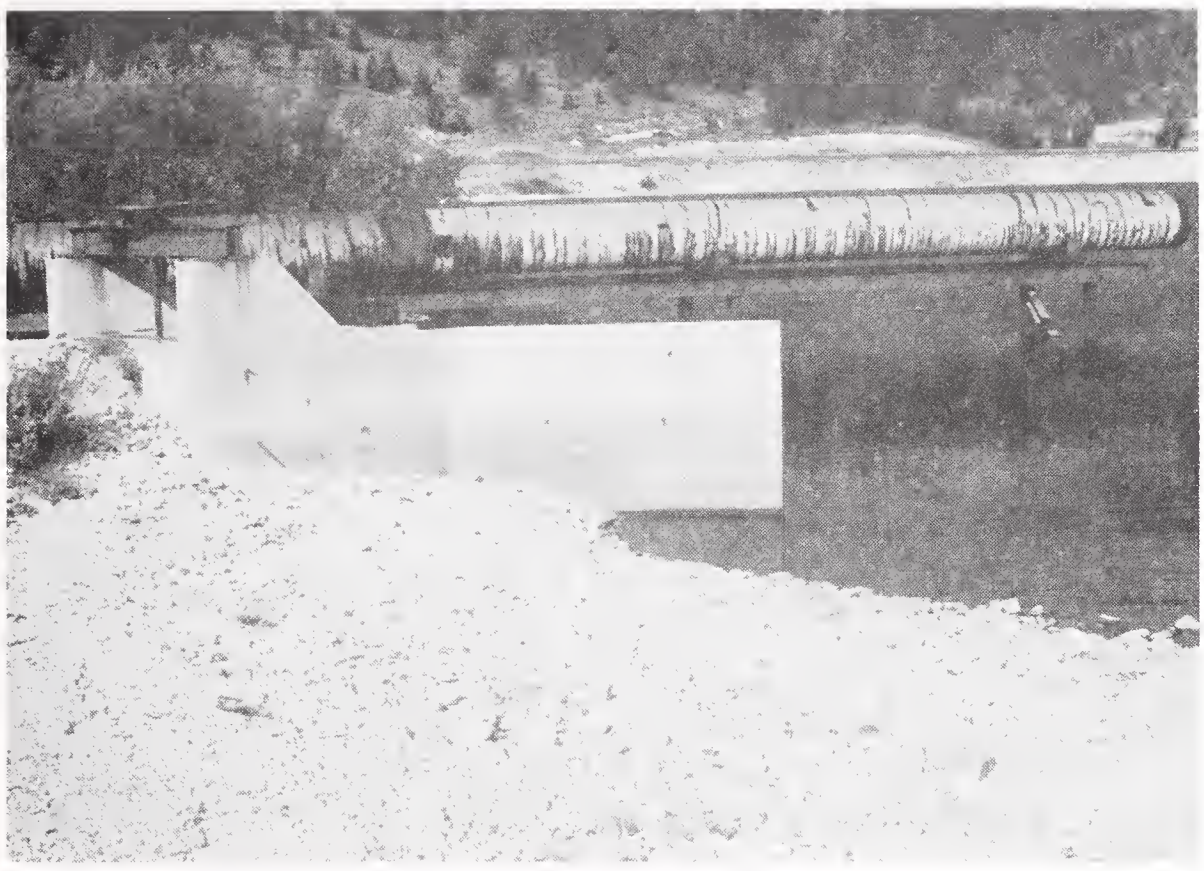


Photo No. 3 - Outlet Works.
Embankment erosion is occurring around the inlet to the west dam outlet works. No riprap protection is provided. The pipe used for pumping water from Georgetown Lake is shown in the background.

Photo No. 4 - Outlet Works.
Shown is the exit of the outlet pipe through the west dam embankment.

Photo No. 5 - Outlet Works.
Concrete cracking is present on the inlet of the west dam outlet works.

Photo No. 6 - Outlet Works.
The outlet works at the east dam consists of a low-level outlet located at the pump station on the earth spur dike and a high-level outlet located at the vertical tower to the left of the truck. The 30-inch wood-stave pipe, which passes flows from both outlets, is visible in the foreground.

Photo No. 7 - Water Supply System.
The earth canal in the foreground supplies water diverted from Storm Lake Creek. The flume in the background delivers water diverted from Twin Lakes Creek. The concrete structure in the middle of the photo is used to control water entering and/or by-passing Silver Lake.

Photo No. 8 - East Dam Embankment.
The maximum embankment cross section is shown in the foreground. Standing seepage water is visible. The spur dike can be seen in the background.

Photo No. 9 - East Dam Embankment.
The upstream face of the embankment is covered with dumped rock riprap. The surface is irregularly shaped.

Photo No. 10 - East Dam Embankment.
The irregular configuration of the slope can be seen. The loose riprap has a nominal size of about 6 inches. There is some debris on the upstream slope.

Photo No. 11 - East Dam Embankment.
This photo shows the right (south) abutment from the spur dike. There is some riprap on the slope in this area. Pine trees and brush are growing on the slope.

Photo No. 12 - East Dam Embankment.
Shown is the dam crest looking from the right (south) abutment looking towards the left (north) abutment. Pine trees are growing on the upstream side of the embankment.

Photo No. 13 - West Dam Embankment.
The maximum dam section is shown here. Seepage water is standing adjacent to the embankment. There are trees growing on the embankment.

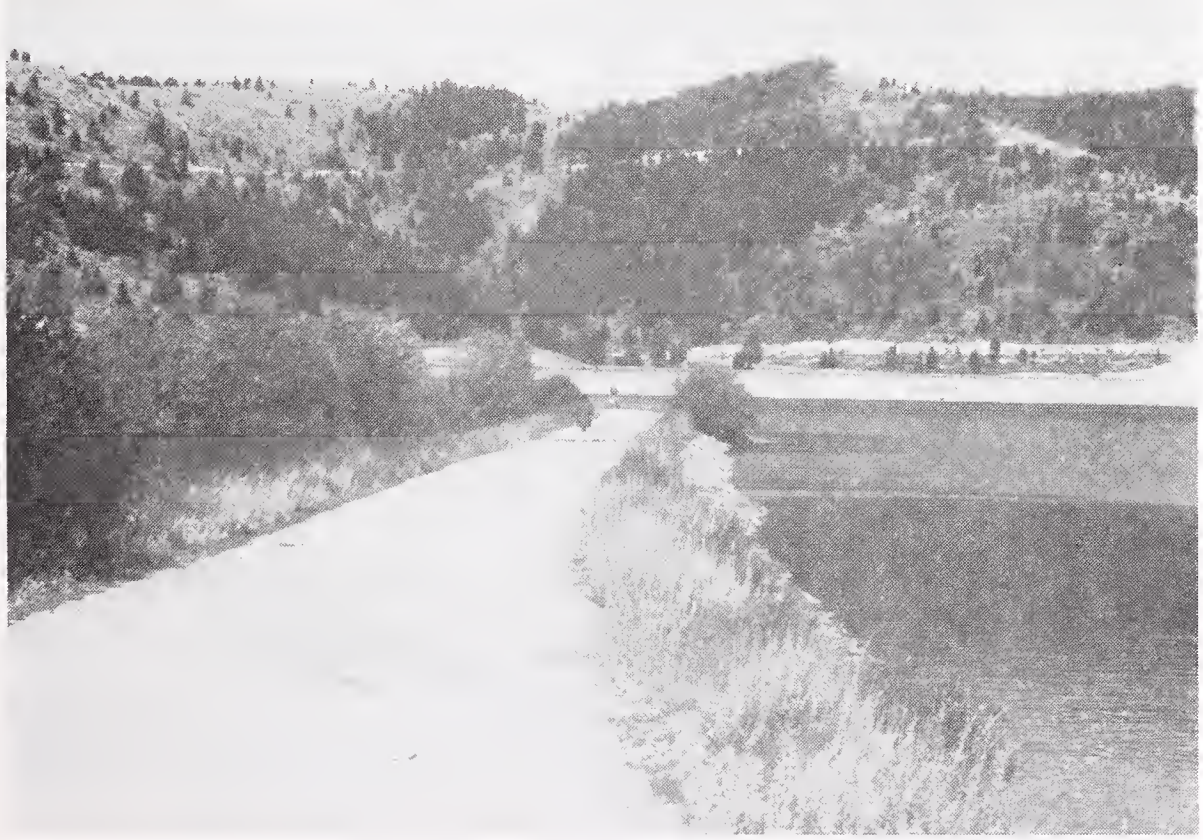


Photo No. 14 - West Dam Embankment.
This photo was taken looking north from near the maximum dam section. Riprap is visible on the upstream face. Brush and trees are growing on both the upstream and downstream slopes.

Photo No. 15 - West Dam Embankment.
Riprap appears adequate at the maximum embankment section. The nominal size at this location is about 8 inches.

Photo No. 16 - West Dam Embankment.
Seepage water is standing at the downstream toe of the embankment. There is a moderate to heavy vegetative cover which includes trees and brush. Topsoil sloughing is evident on this slope.

Photo No. 17 - West Dam Embankment.
This photo was taken looking towards the right (north) abutment. The vehicle is parked near the bridge. Water is ponded on the crest and trees are growing on both slopes.

APPENDIX C

PROJECT DRAWINGS

EXHIBIT C1	PLAN VIEW, SILVER LAKE EAST DAM
EXHIBIT C2	PLAN VIEW, SILVER LAKE WEST DAM
EXHIBIT C3	TYPICAL EMBANKMENT SECTION, SILVER LAKE EAST DAM
EXHIBIT C4	TYPICAL EMBANKMENT SECTION, SILVER LAKE WEST DAM
EXHIBIT C5	DAM CREST PROFILE, SILVER LAKE EAST DAM
EXHIBIT C6	DAM CREST PROFILE, SILVER LAKE WEST DAM

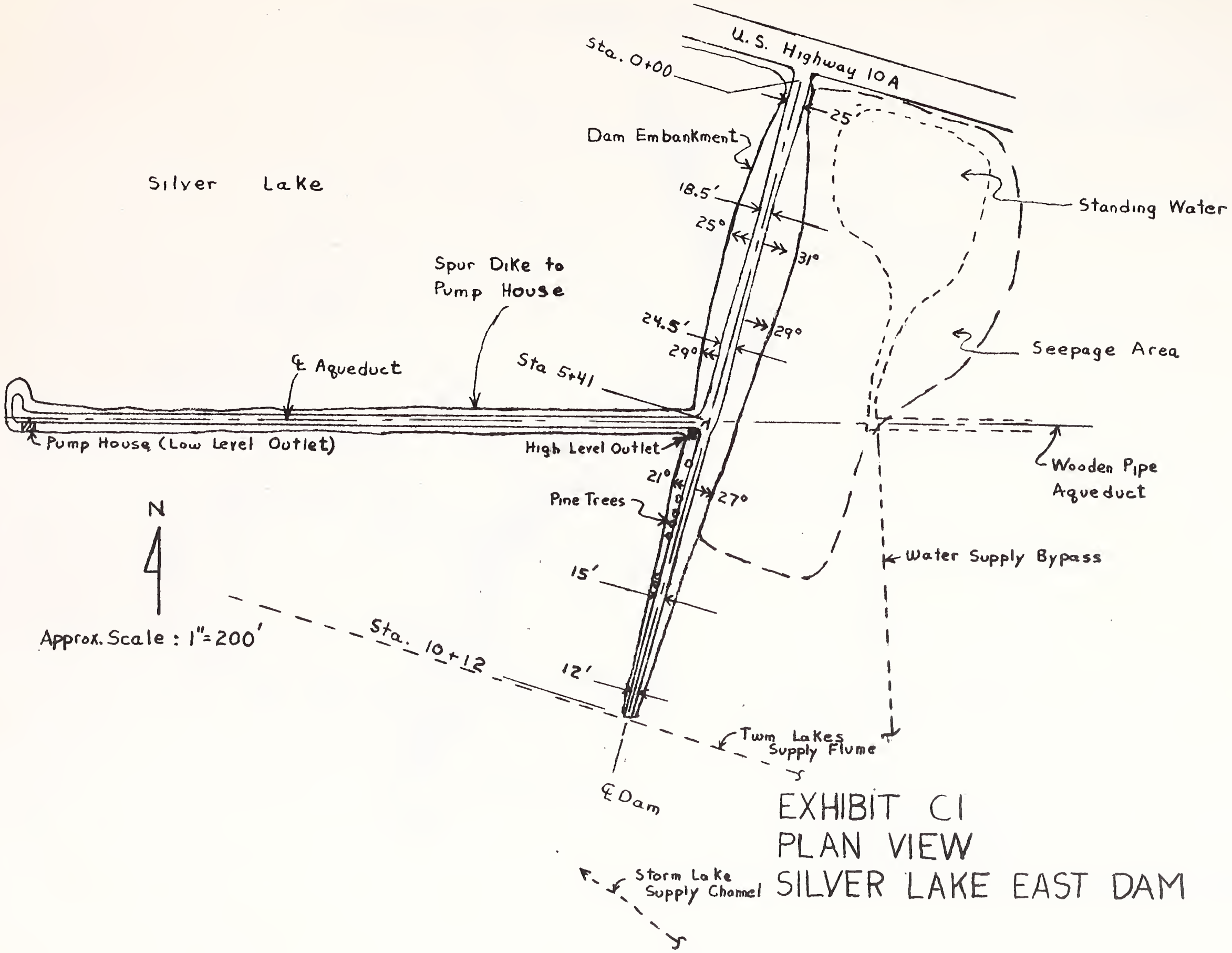


EXHIBIT C1
PLAN VIEW
SILVER LAKE EAST DAM

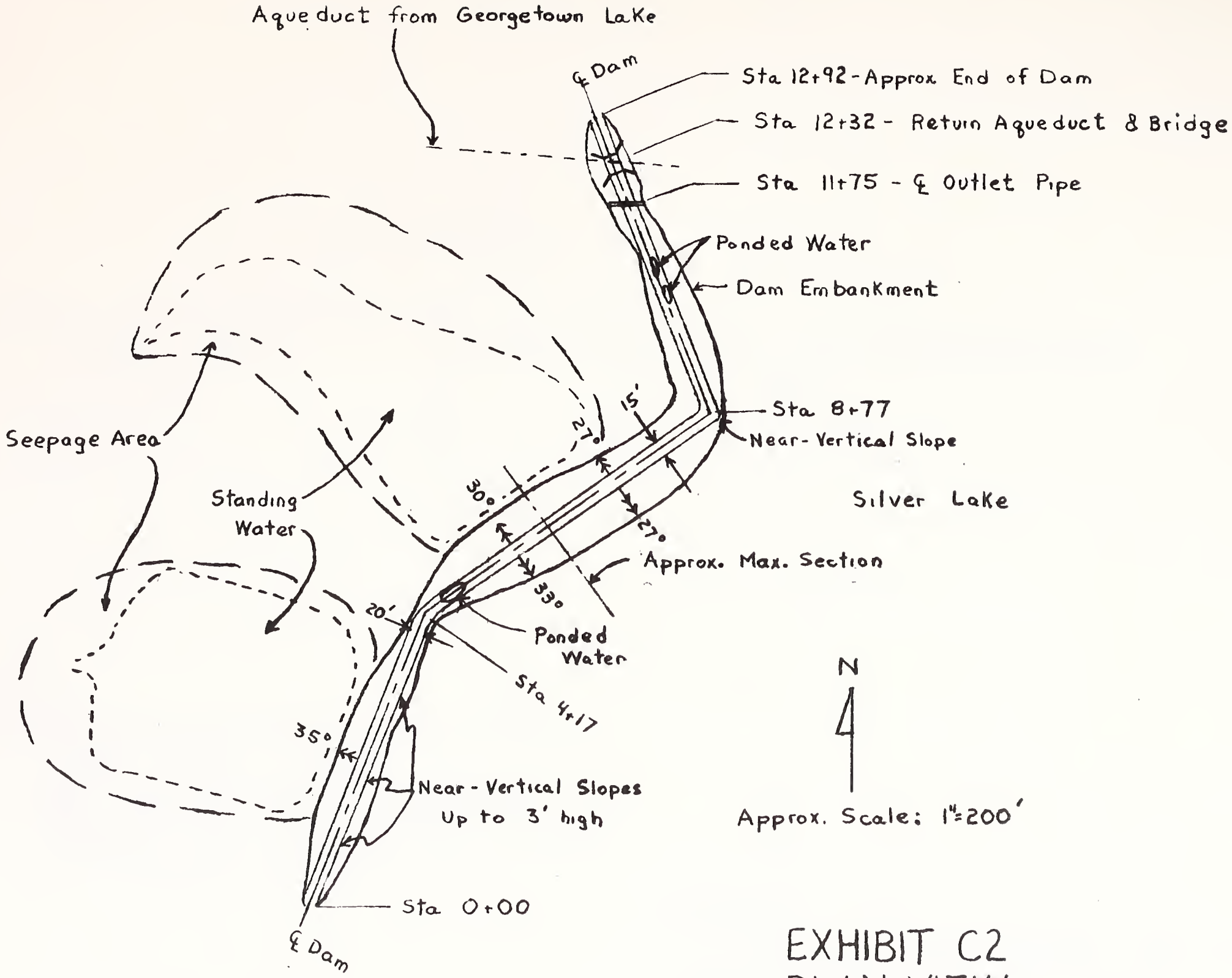
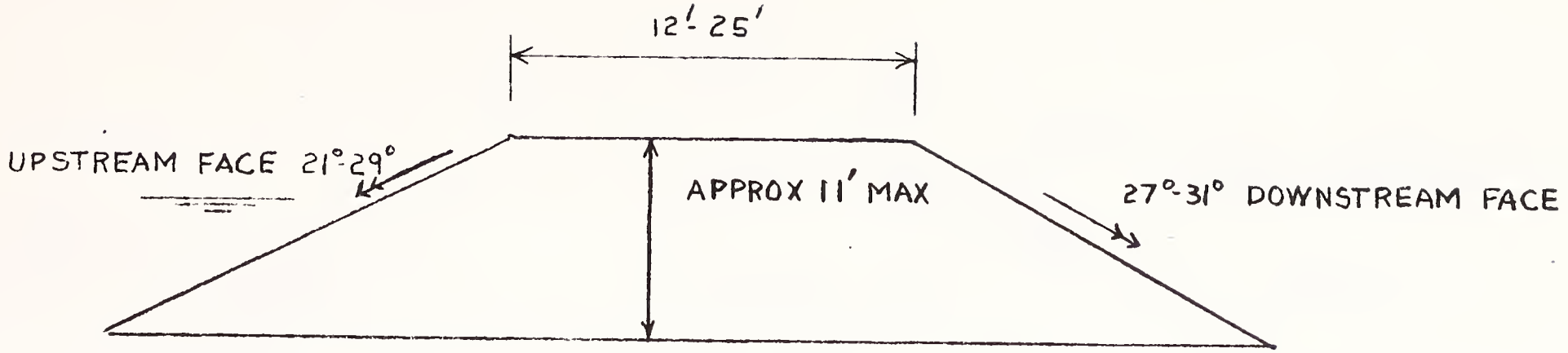


EXHIBIT C2
PLAN VIEW
SILVER LAKE WEST DAM

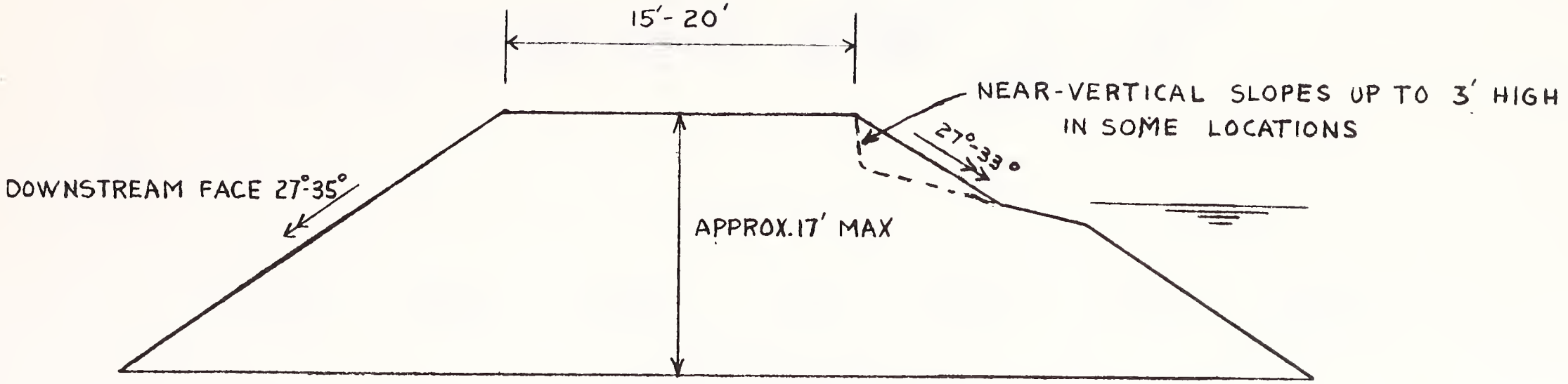


NO SCALE

NOTES:

1. SECTION DEVELOPED FROM HKM FIELD SURVEY DATA 9-30-80
2. SEE EXHIBIT C1, PLAN VIEW, FOR LOCATIONS OF VARYING CREST WIDTHS & EMBANKMENT SLOPES

EXHIBIT C3
TYPICAL EMBANKMENT SECTION
SILVER LAKE EAST DAM

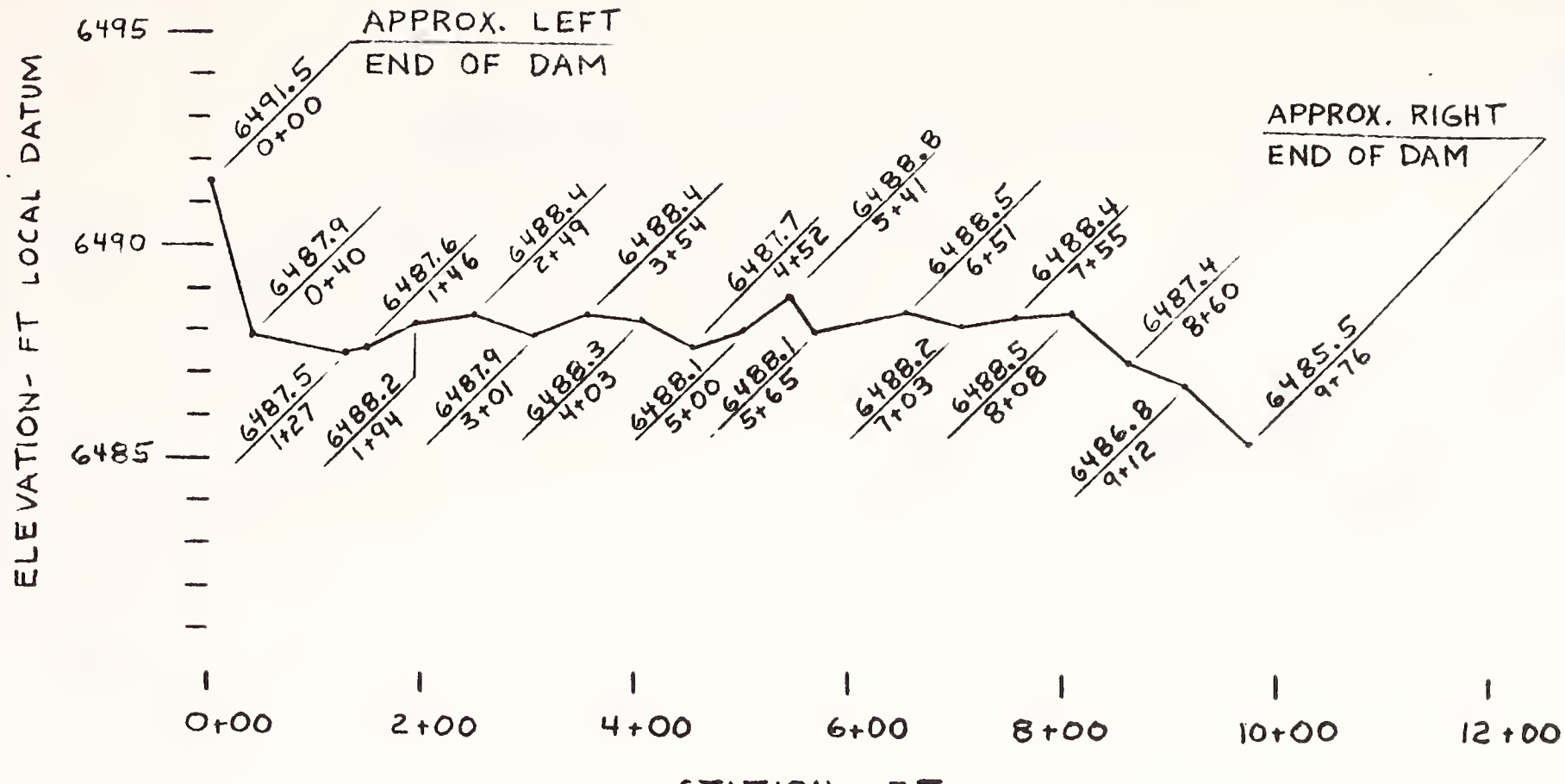


NO SCALE

NOTES:

1. SECTION DEVELOPED FROM HKM FIELD SURVEY DATA, 9-30-80
2. SEE EXHIBIT C2, PLAN VIEW, FOR LOCATIONS OF VARYING CREST WIDTHS & EMBANKMENT SLOPES.

EXHIBIT C4
TYPICAL EMBANKMENT SECTION
SILVER LAKE WEST DAM

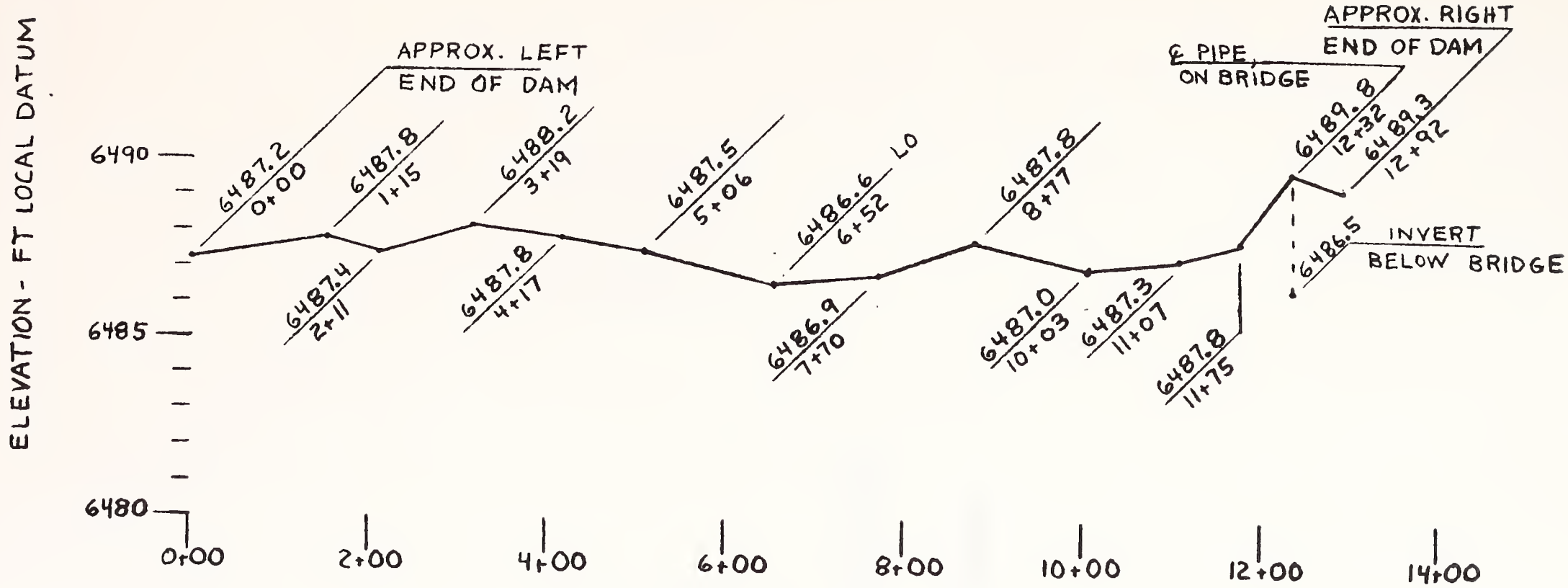


Scale : 1"=200'H, 1"=5' V

NOTES:

1. PROFILE FROM HKM SURVEY, 9-30-80
2. ELEVATIONS BASED ON STAFF GAGE READING OF WATER SURFACE = 6482.15 FT (LOCAL DATUM)

EXHIBIT C5
DAM CREST PROFILE
SILVER LAKE EAST DAM



Scale : 1"= 200'H, 1"= 5'V

NOTES:

1. PROFILE FROM HKM SURVEY, 9-30-80
2. ELEVATIONS BASED ON STAFF GAGE READING OF WATER SURFACE = 6482.15 FT (LOCAL DATUM)

EXHIBIT C 6
DAM CREST PROFILE
SILVER LAKE WEST DAM

APPENDIX D

ENGINEERING DATA

EXHIBIT D1	ELEVATION-CAPACITY-AREA CURVES
EXHIBIT D2	DISCHARGE RATING TABLE
EXHIBIT D3	DISCHARGE RATING CURVES

AREA - ACRES

350 300 250 200 150 100 50 0

RESERVOIR ELEVATION - FT (LOCAL DATUM)

6500 6480 6460 6440 6420 6400 6380

EXTRAPOLATED

FIRST OVERTOPPING EL 6485.5'

EXTRAPOLATED

CAPACITY

AREA

RESERVOIR ELEVATION (FT)	AREA (Acres)	CAPACITY (A F)
6385	0	0
6400	64	241
6420	150	2552
6440	212	6188
6460	246	10740
6480	304	16120
FIRST OVERTOPPING EL 6485.5	350 *	17920 *

* Extrapolated

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

CAPACITY - THOUSAND ACRE-FEET

EXHIBIT D1
ELEVATION- CAPACITY - AREA CURVES
SILVER LAKE

EXHIBIT D2

DISCHARGE RATING TABLE

SILVER LAKE

RESERVOIR ELEVATION (FT, LOCAL DATUM)	OUTLET WORKS DISCHARGE WEST DAM (CFS)	HIGH-LEVEL OUTLET DISCHARGE EAST DAM (CFS)
6477.5 (Inlet El. Outlet Works)	0	-
6478	5	-
6479 (Est. Inlet El. High-Level Outlet)	16	0
6480	34	10
6482	80	34
6484	112	37
6485.5 (First Overtopping El.)	130	39

Note:
At Silver Lake East Dam, approx. maximum pumping discharge capacity is 350 cfs through low-level outlet.

DISCHARGE OF HIGH-LEVEL OUTLET (EAST DAM) - CFS

0 5 10 15 20 25 30 35 40

RESERVOIR ELEVATION - FT LOCAL DATUM

6490
6485
6480
6475
6470

OUTLET WORKS, WEST DAM

FIRST OVERTOPPING EL 6485.5

HIGH-LEVEL OUTLET, EAST DAM

NOTE:
AT SILVER LAKE EAST DAM, THE MAXIMUM PUMPING DISCHARGE CAPACITY IS APPROX. 350 CFS THROUGH THE LOW-LEVEL OUTLET.

0 25 50 75 100 125 150

DISCHARGE OF OUTLET WORKS (WEST DAM) - CFS

EXHIBIT D3
DISCHARGE RATING CURVE
SILVER LAKE

APPENDIX E

CORRESPONDENCE

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
WATER RESOURCES DIVISION

TED SCHWINDEN, GOVERNOR

32 SOUTH EWING

STATE OF MONTANA

(406) 449-2872 ADMINISTRATOR
(406) 449-3962 WATER RIGHTS BUREAU
(406) 449-2872 WATER SCIENCES BUREAU
(406) 449-2864 ENGINEERING BUREAU
(406) 449-2872 WATER PLANNING BUREAU

HELENA, MONTANA 59620

April 29, 1981

Ralph Morrison
Department of the Army
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, Washington 98124

Dear Mr. Morrison:

The Department of Natural Resources and Conservation has reviewed the final draft report on the Silver Lake Dams (MT-375 & MT-3753). We concur with the findings and recommendations and feel that the report satisfies the criteria for the Phase I evaluation. Minor comments have been discussed with your staff and we understand that these will be included in the final report.

Thank you for this opportunity to review and comment on the final draft report for this project.

Sincerely,

Richard L. Bondy

Richard L. Bondy, P.E.
Chief, Engineering Bureau

RB/LT/lz

"AN EQUAL OPPORTUNITY EMPLOYER"

ANACONDA Copper Company

555 Seventeenth Street
Denver, Colorado 80217
Telephone 303 575-4272
Richard Krablin, Ph. D.
Manager - Health, Safety and Environment

April 3, 1981

Sidney Knutson, P. E.
Assistant Chief, Engineering Division
Department of the Army
Seattle District, Corps of Engineers
P.O.Box c-3755
Seattle, Washington 98124

Dear Mr. Knutson:

Anaconda Copper Company has received the Phase I Inspection Report on the Silver Lake project dated Fevruary 1981 and we are contracting with a reputable geotechnical firm to proceed with the Phase 2 investigation.

Once we have received the Phase 2 report, a copy of it will be forwarded to the Governor of the State of Montana.

Sincerely,

Richard Krablin.

Richard Krablin, Ph.D.
Manager - Health, Safety & Environment

RK/LF/jb

cc: Mr. Leroy Berry
Director, Department of Natural Resources and Conservation
32 S. Ewing
Helena, Montana 59601

ANACONDA COPPER